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Does high order and dynamic adaptive mesh refinement improved the efficiency of atmospheric simulations?

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Does high order and dynamic adaptive mesh refinement improve the efficiency of atmospheric simulations?

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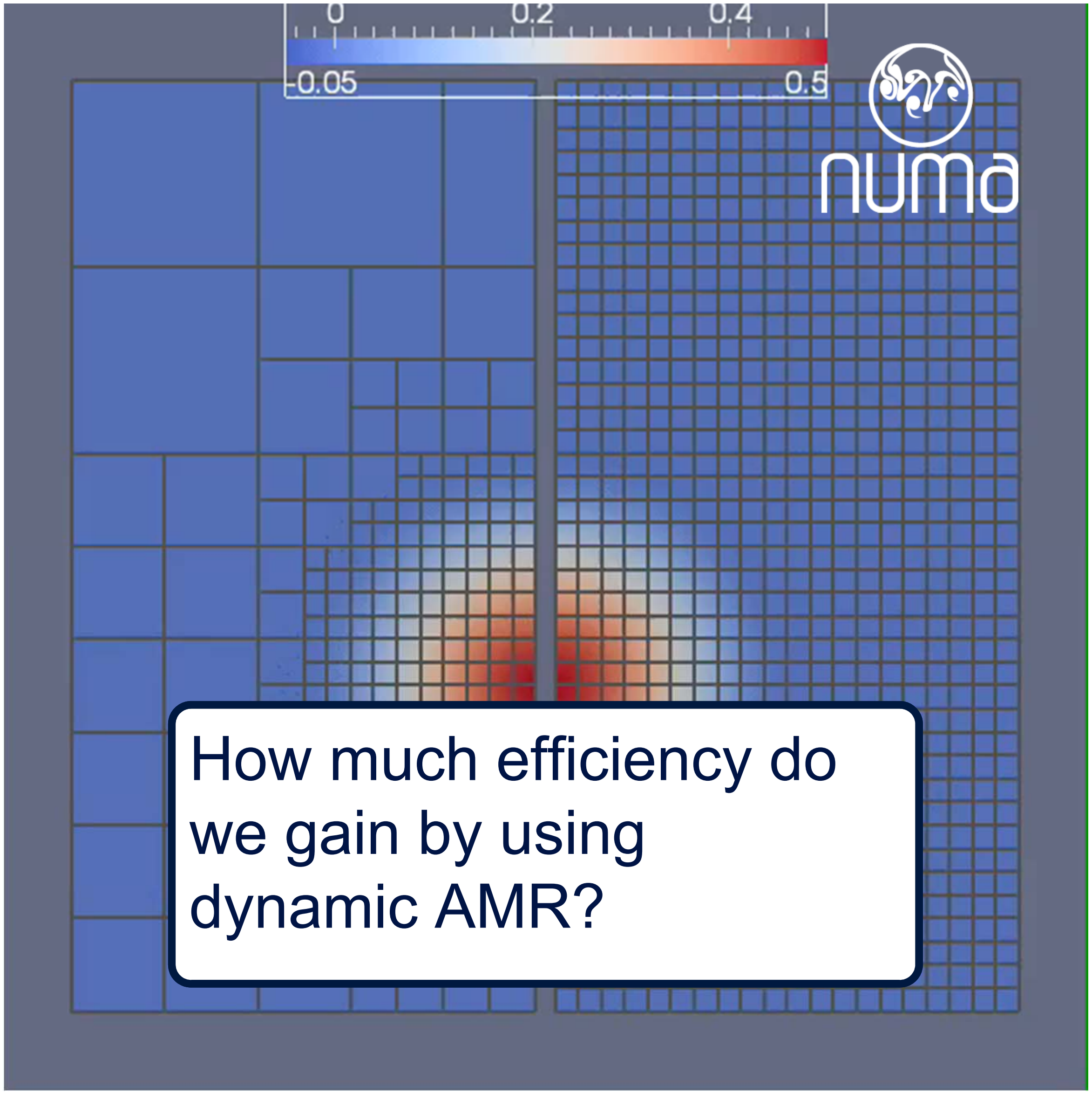
overview

- Motivation
- Results: what do we gain by using AMR and high order?
- Next steps

Motivation

Warm air bubble test case with $\mu = 0.1 m^2/s$



How much efficiency do we gain by using dynamic AMR?

Goal

methods

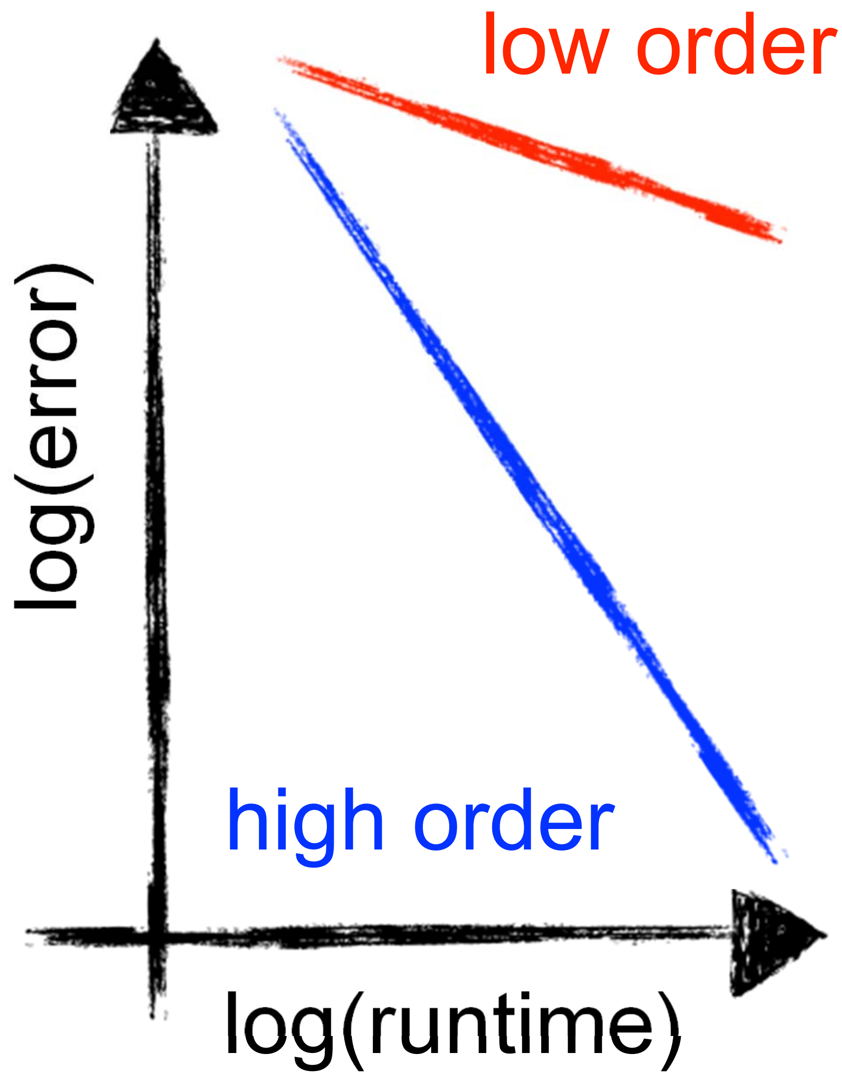
- dynamic AMR, uniform meshes
- high order, low order

applications

- cloud simulations
- Hurricane simulations

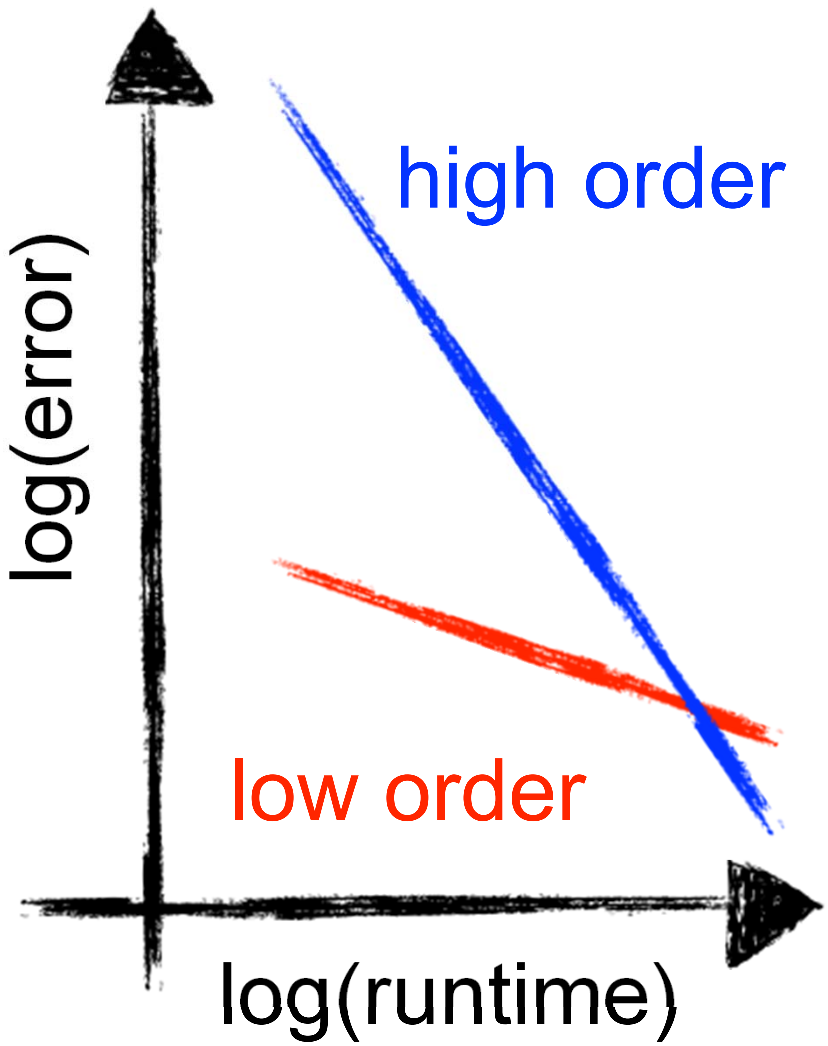
For which of these applications should we use these methods and how should we use them?

High vs. low order
theoretical expectations



High vs. low order

theoretical expectations



High vs. low order

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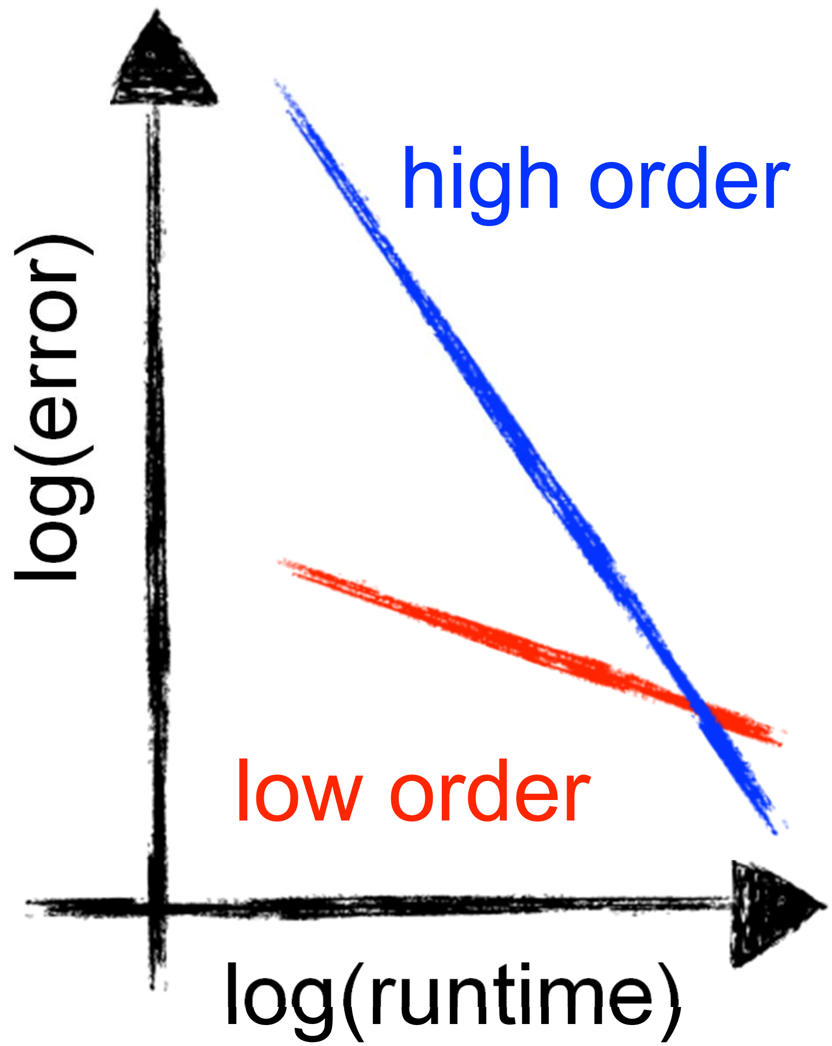


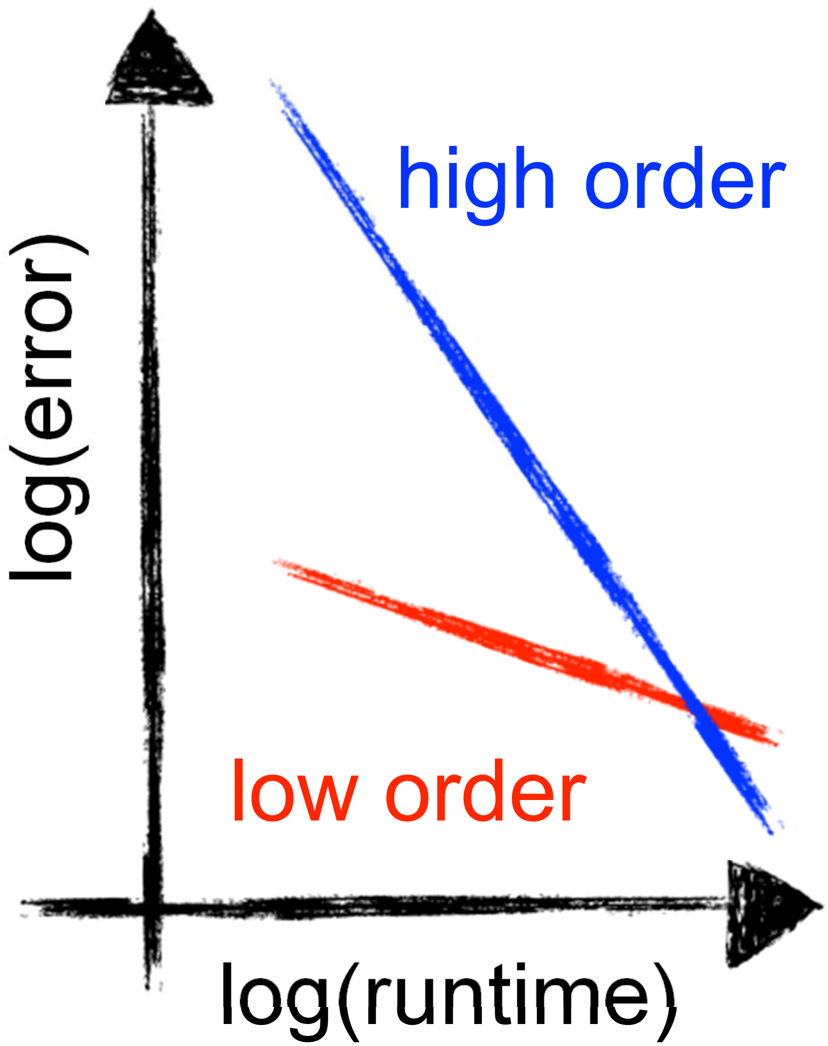
difficulties

- need convergence

➡add small amount of viscosity (such that highest possible resolution can be called truth)

High vs. low order

theoretical expectations



difficulties

- need convergence
  ➡add small amount of viscosity (such that highest possible resolution can be called truth)
- it is impossible to compare numerical methods. The runtime depends on the specific implementation!
  ➡keep as much code as possible unchanged

NUMA

Non-hydrostatic Unified Model of the Atmosphere

- **dynamical core** inside the Navy's next generation weather prediction system NEPTUNE
- **unified across numerics** (contains Continuous and Discontinuous Galerkin methods)
- **unified across applications** (regional and global modeling)
- 3D, DG, MPI: **strong scaling** for explicit time integration (tested up to 32000 CPUs)
- 2D, serial: allows **dynamic AMR**

work in progress:

- 3D dynamic AMR
- GPU version

Questions for Today

Results for 2D bubble test cases simulated with NUMA

Questions:

1. Does high-order improve the efficiency?

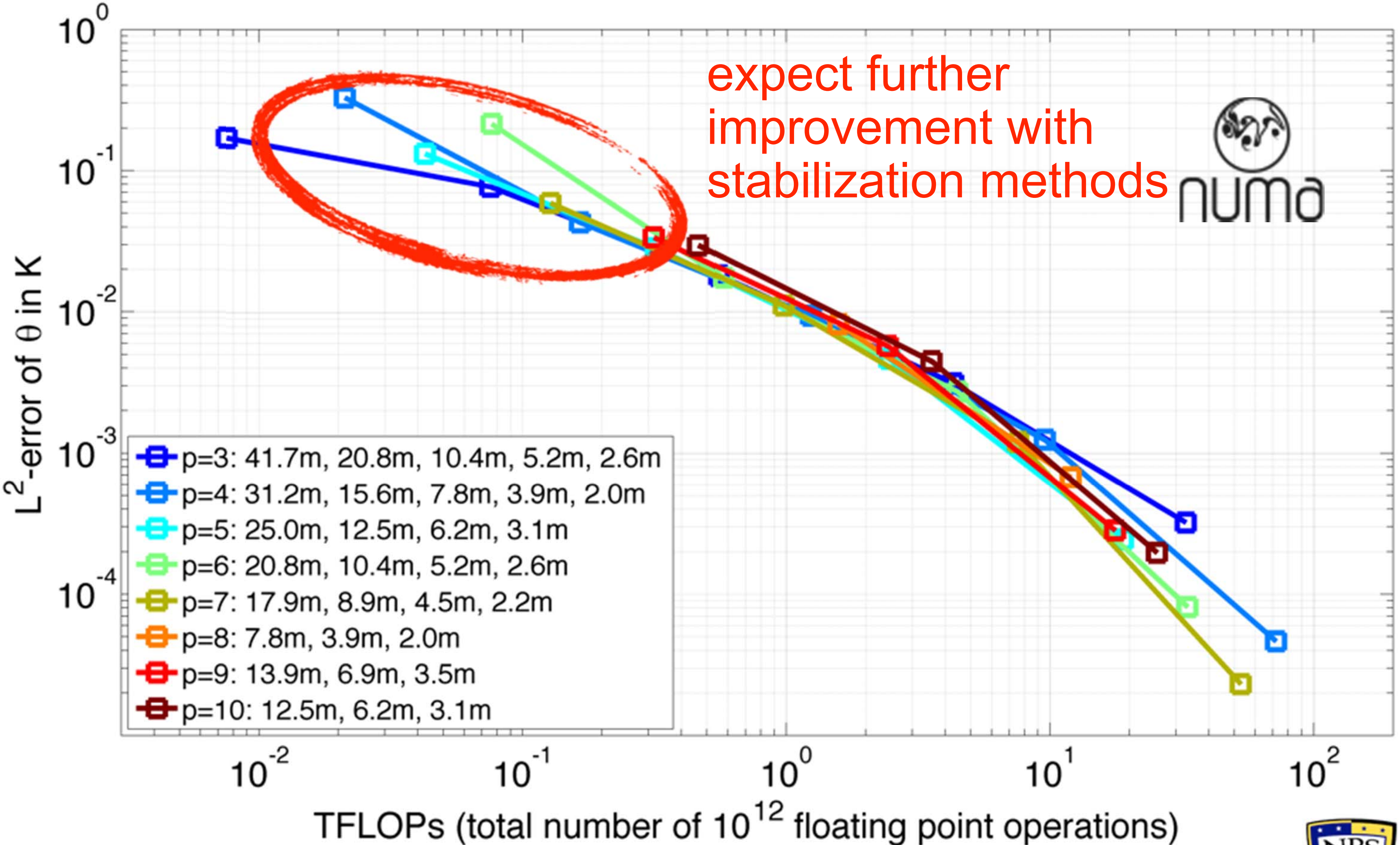
Results:

2. Does dynamic adaptive mesh refinement improve the efficiency?

3. Do moist dynamics reduce the order of convergence?

L^2-error of uniform simulations

as a function of number of floating point operations



Questions for Today

Results for 2D bubble test cases simulated with NUMA

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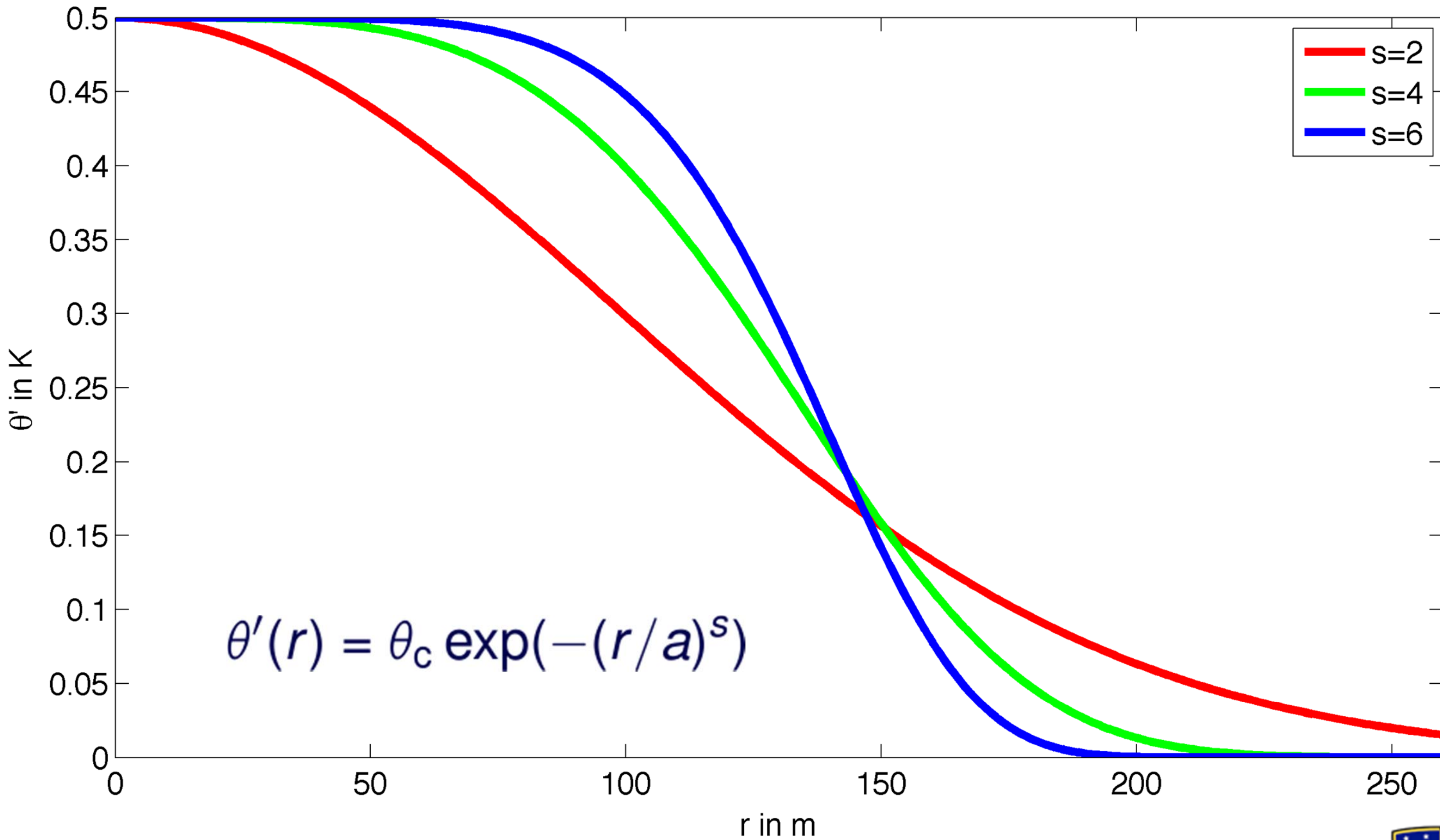
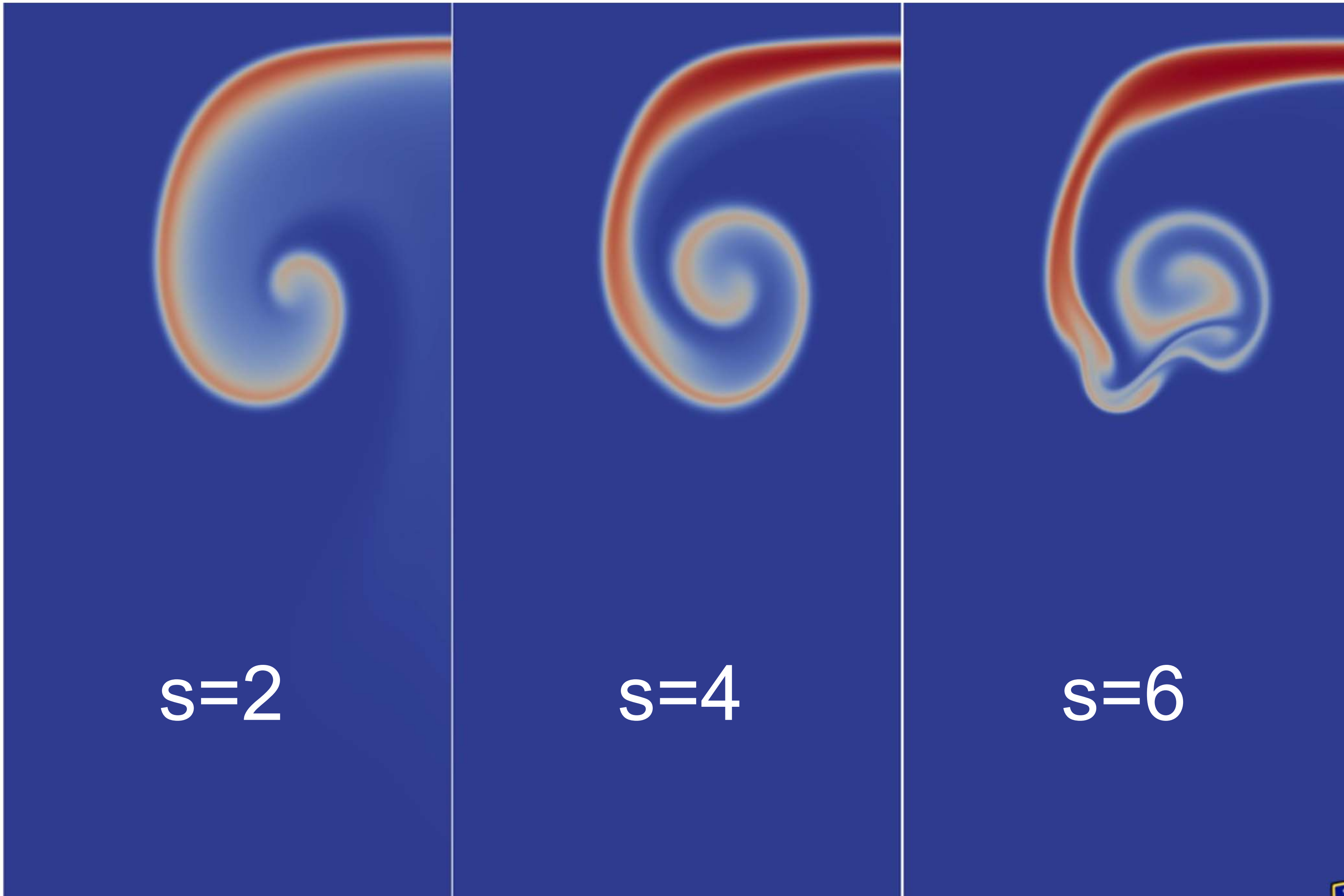
Three different initial profiles for *θ'*

as a function of distance from the center of the bubble *r*



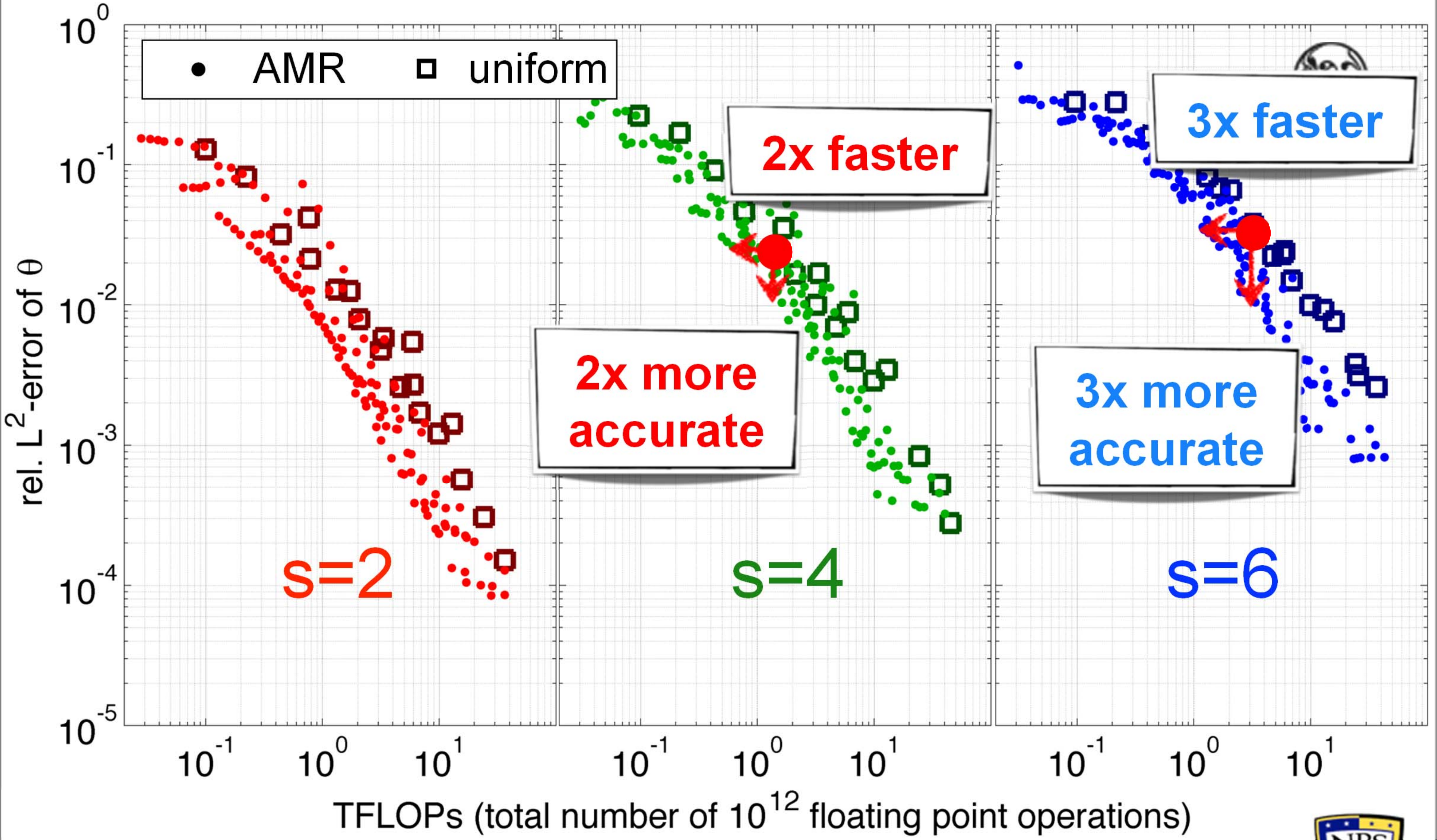
Reference result for 3 different bubbles

resolution Δx = 40cm, time t=700s



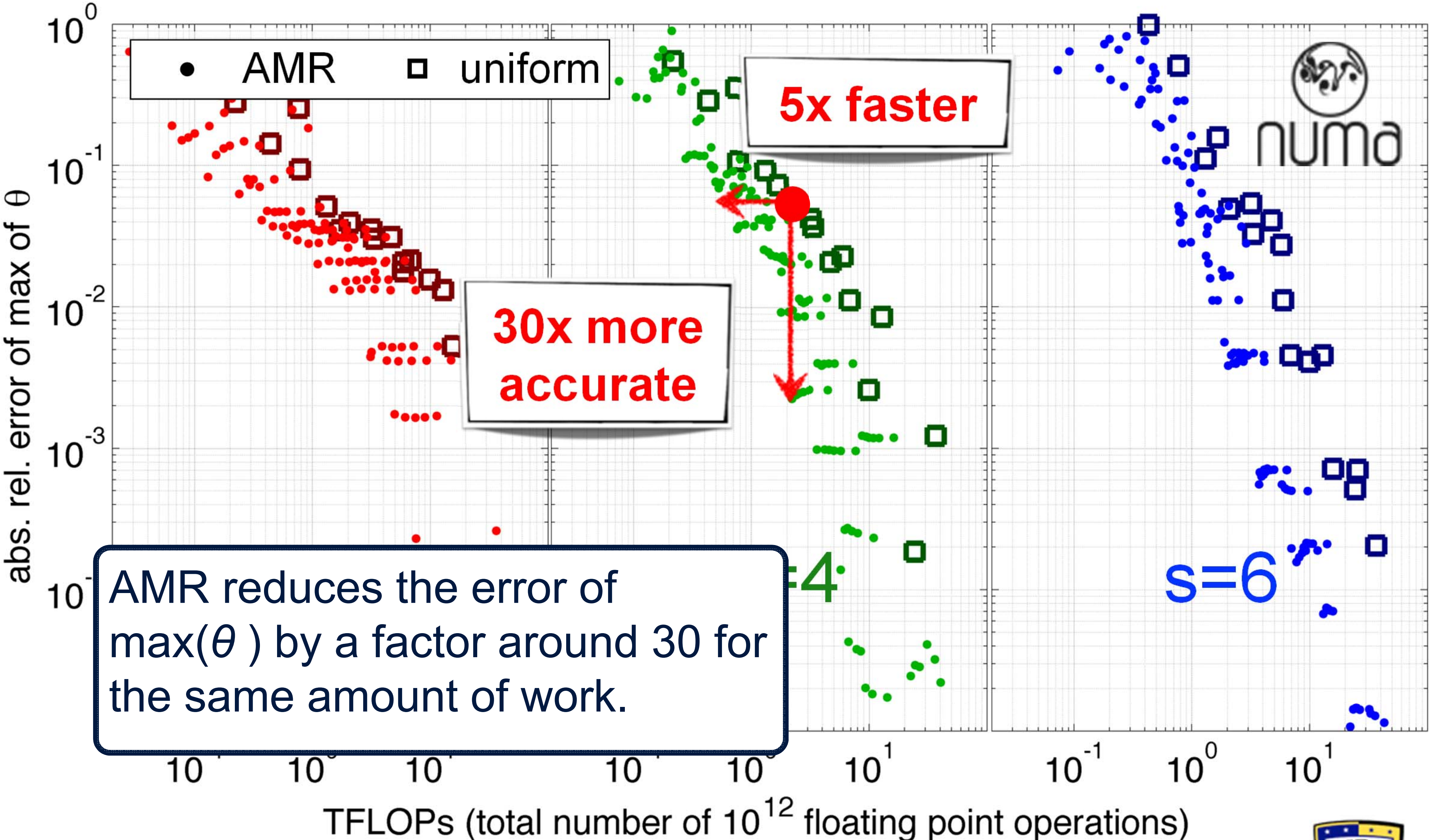
L^2-error for 3 different initial conditions

viscosity: μ=0.1m^2/s



relative error of max(θ)

viscosity: μ=0.1m^2/s



AMR reduces the error of max(θ) by a factor around 30 for the same amount of work.

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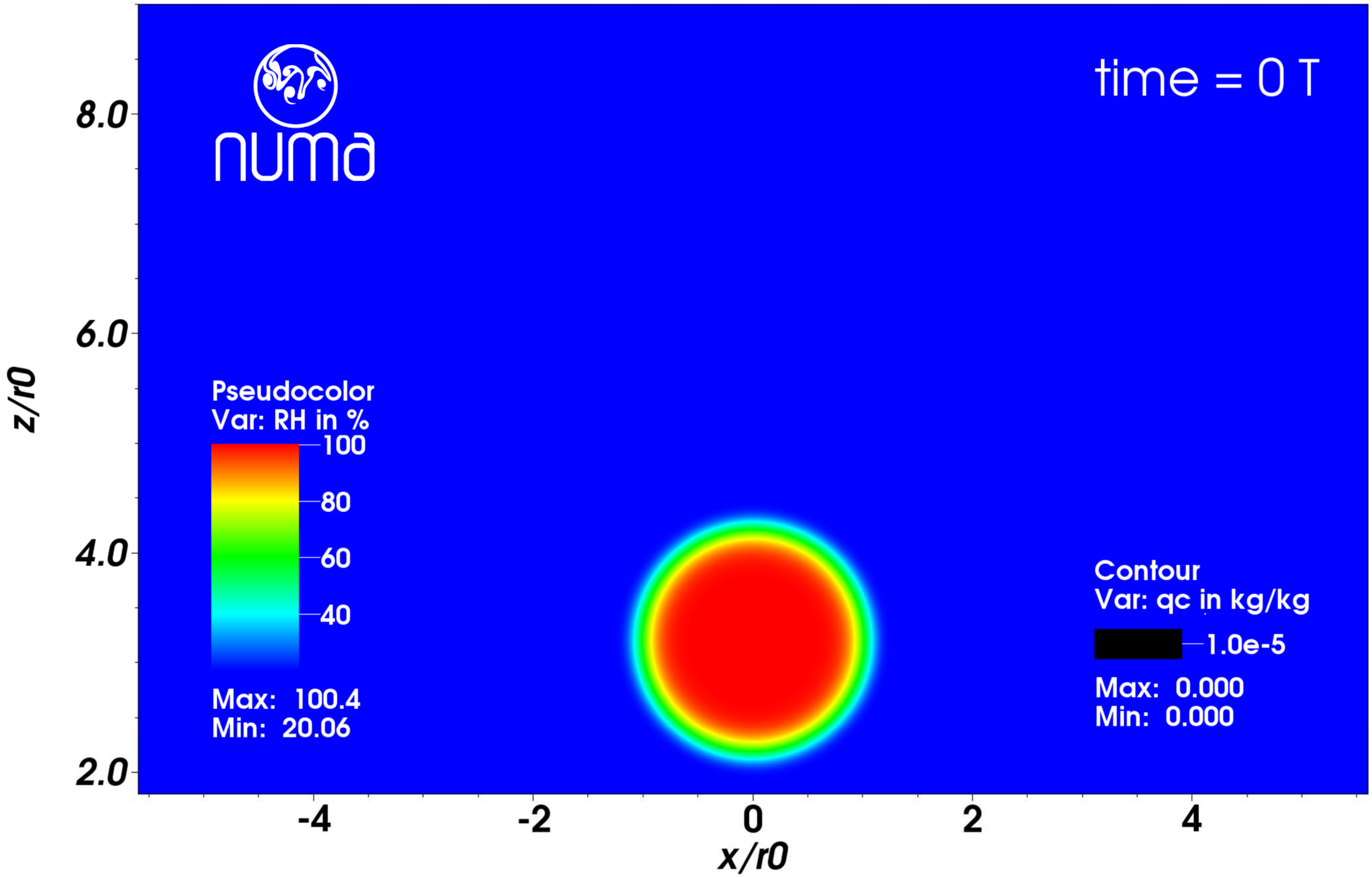
moist bubble

from Kurowski et al. (2013). Viscosity: μ=2.5m^2/s



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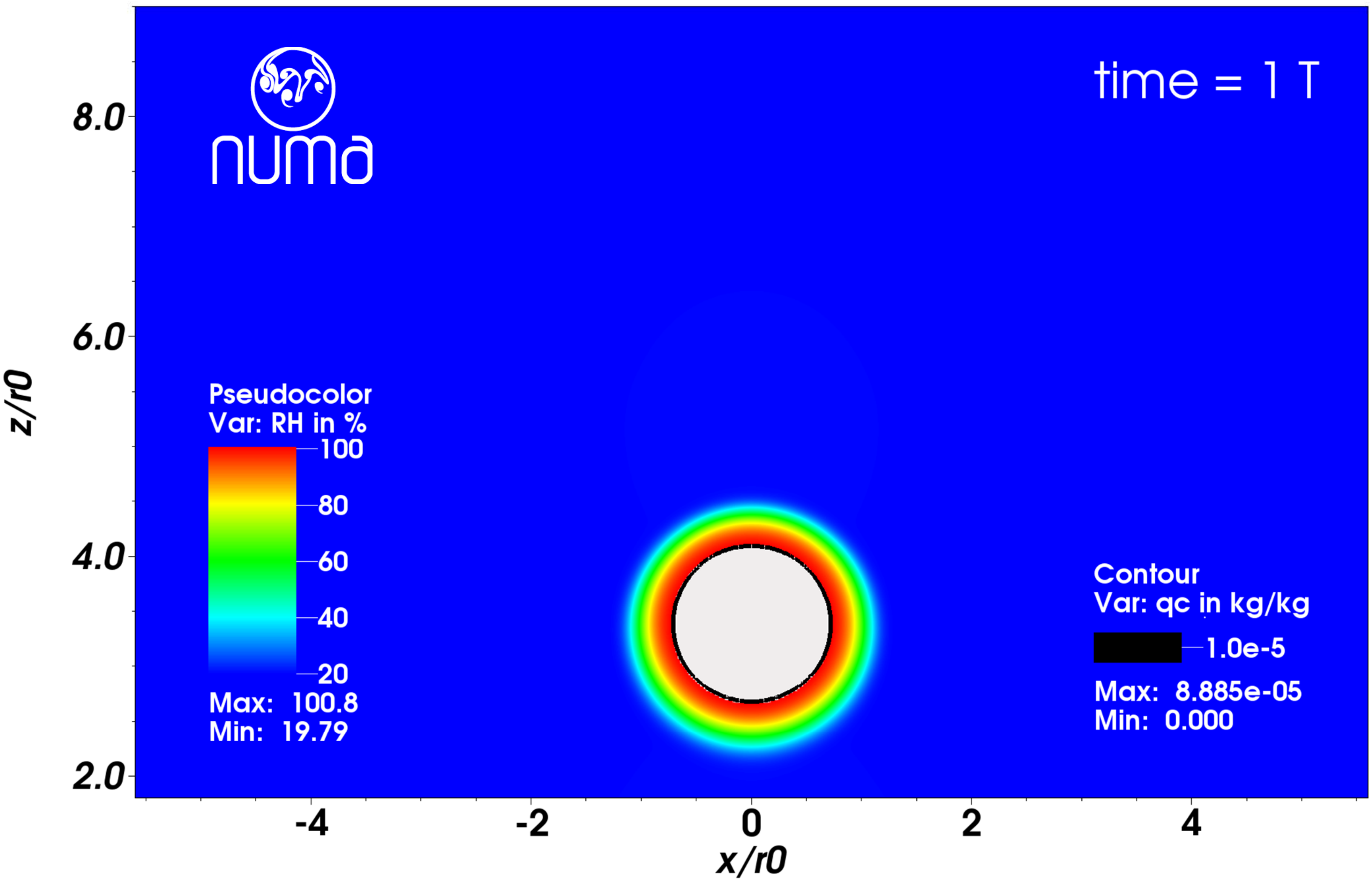

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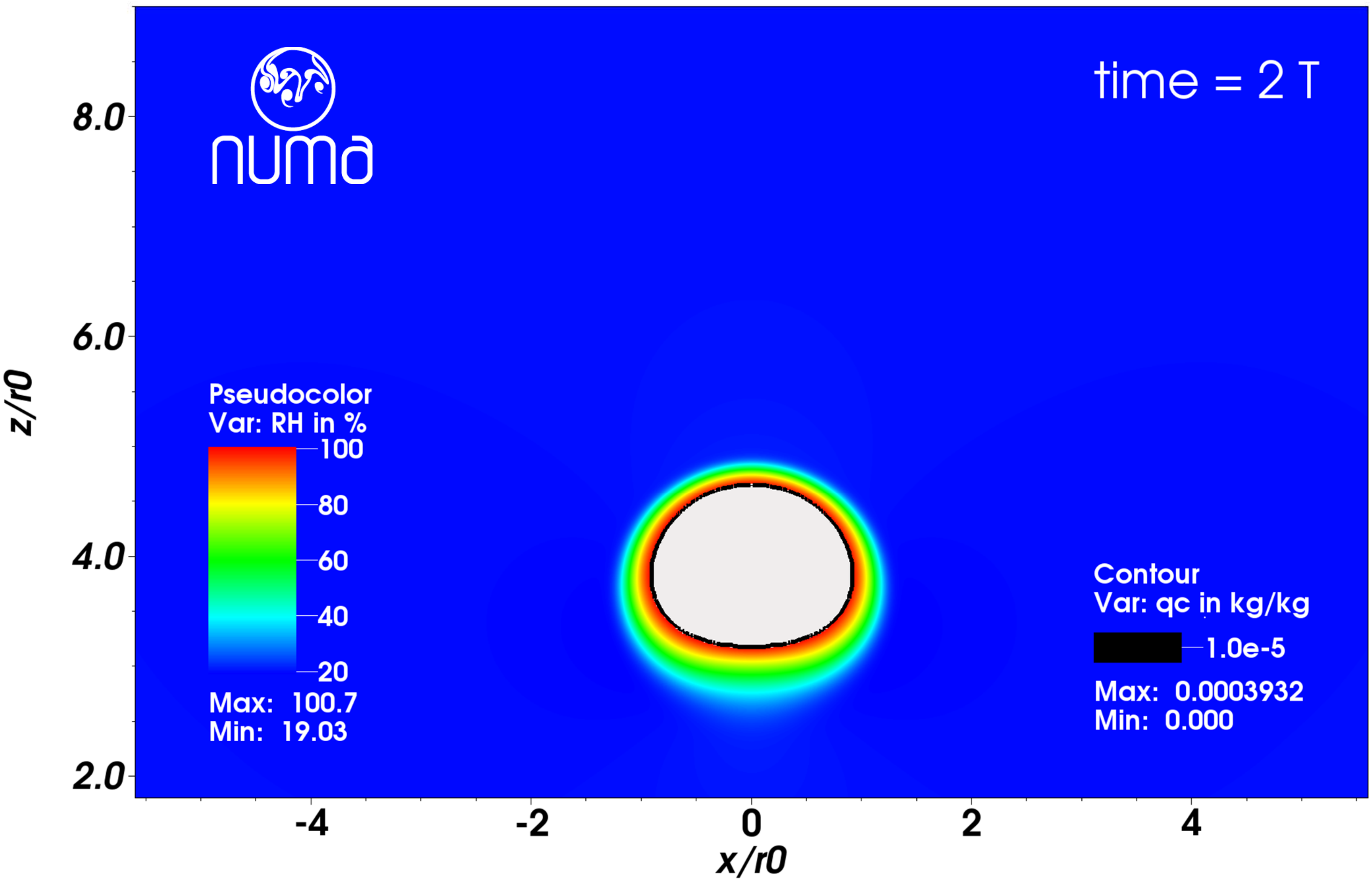

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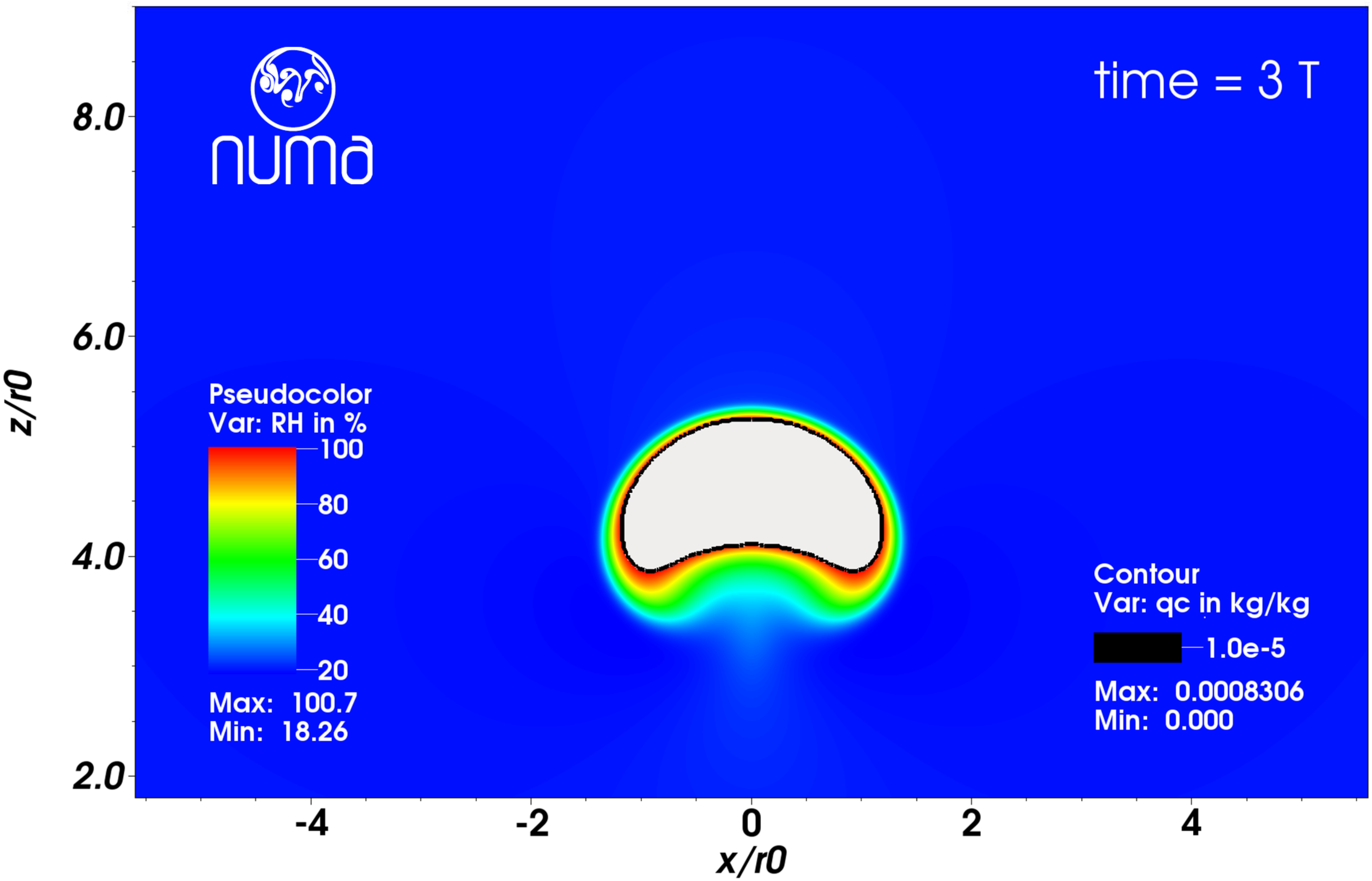

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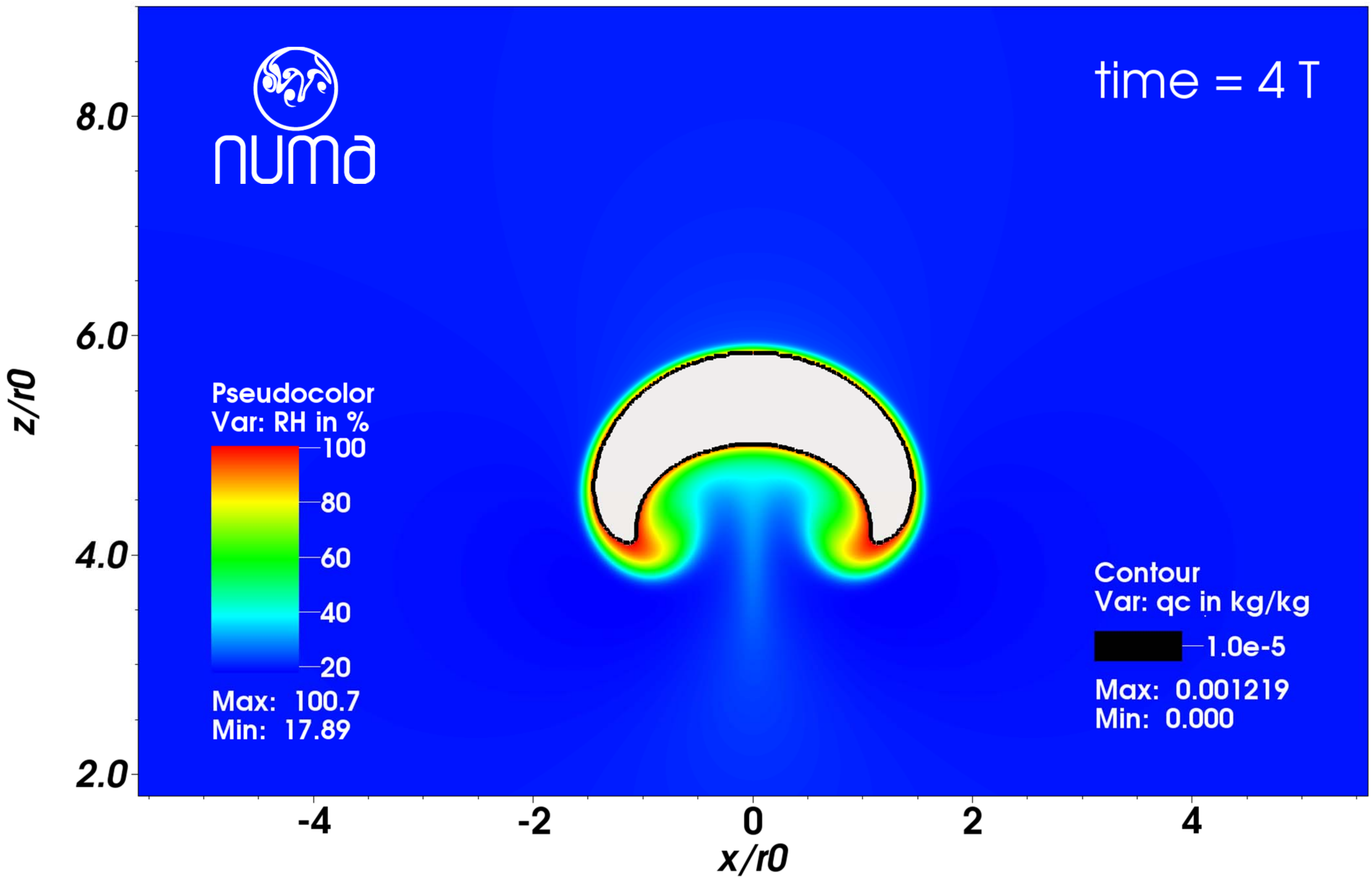

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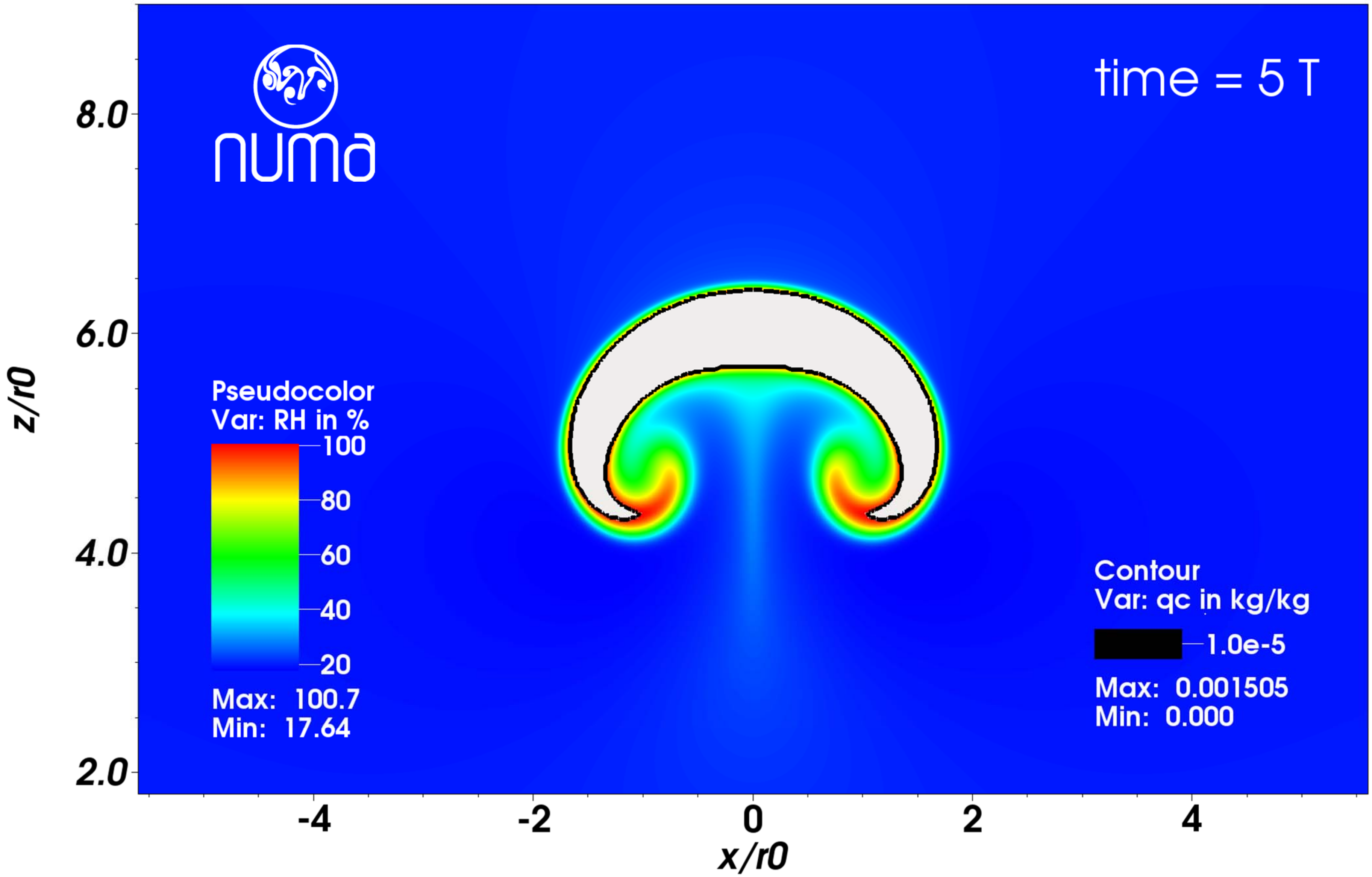

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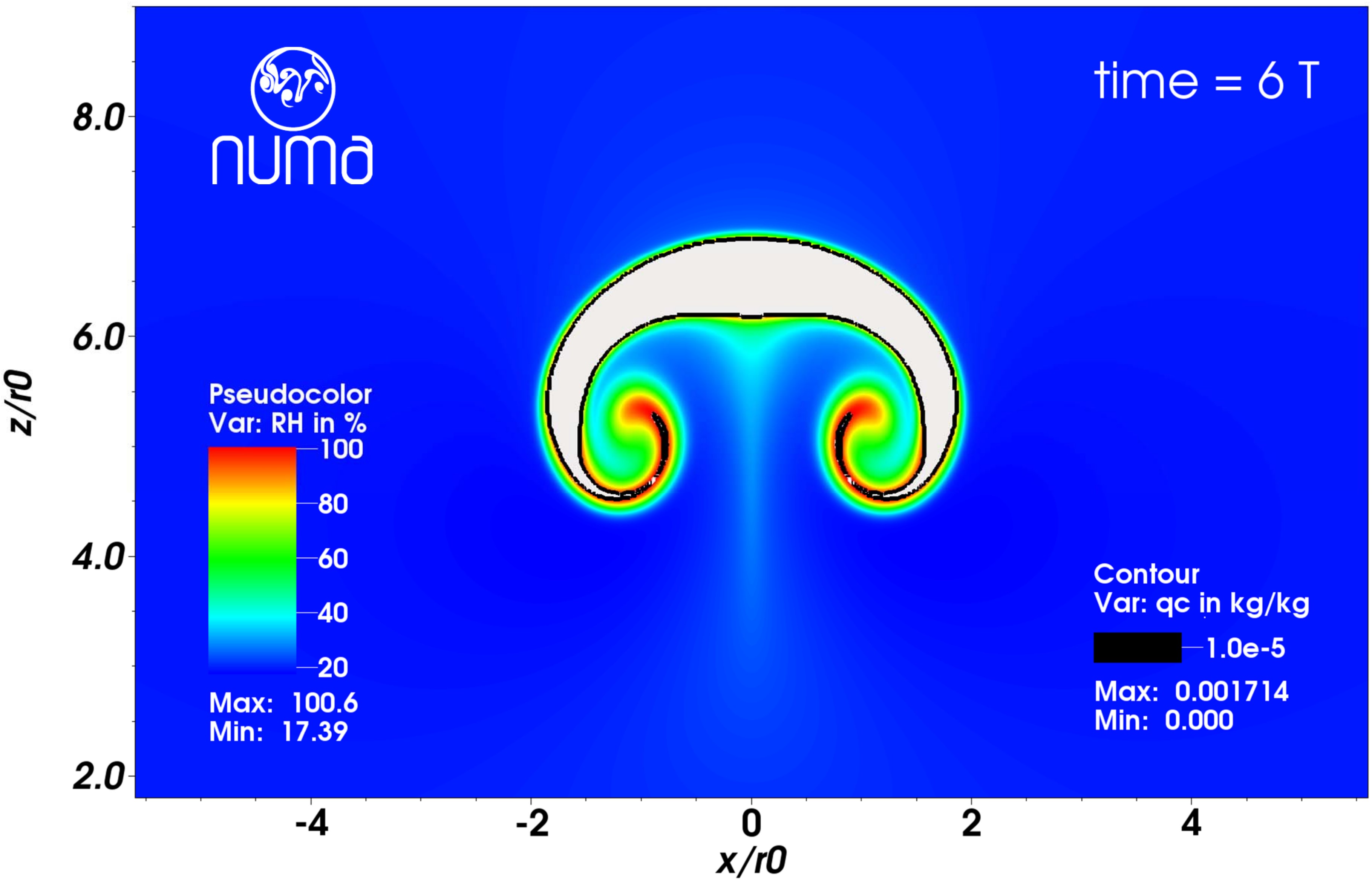

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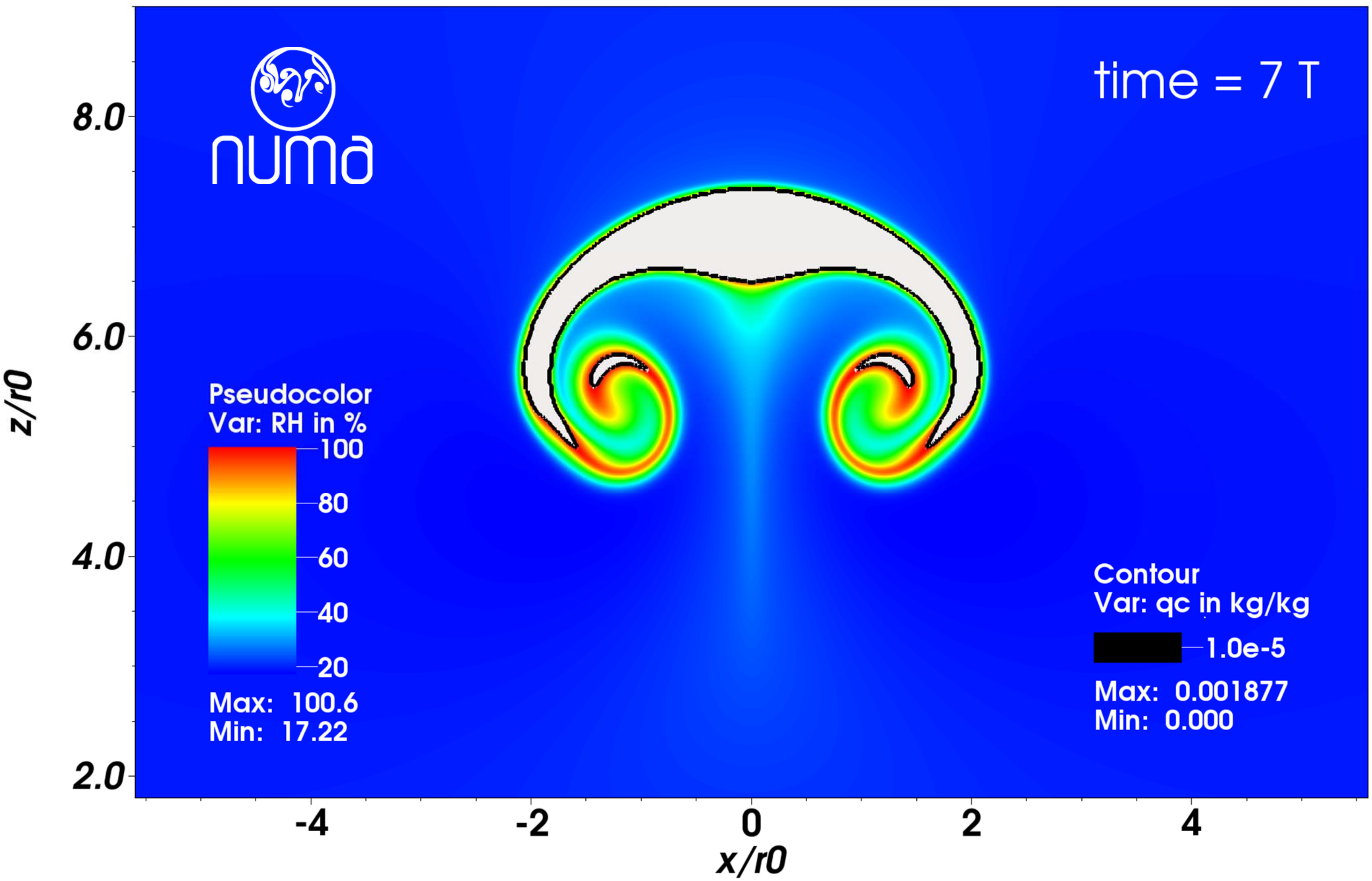

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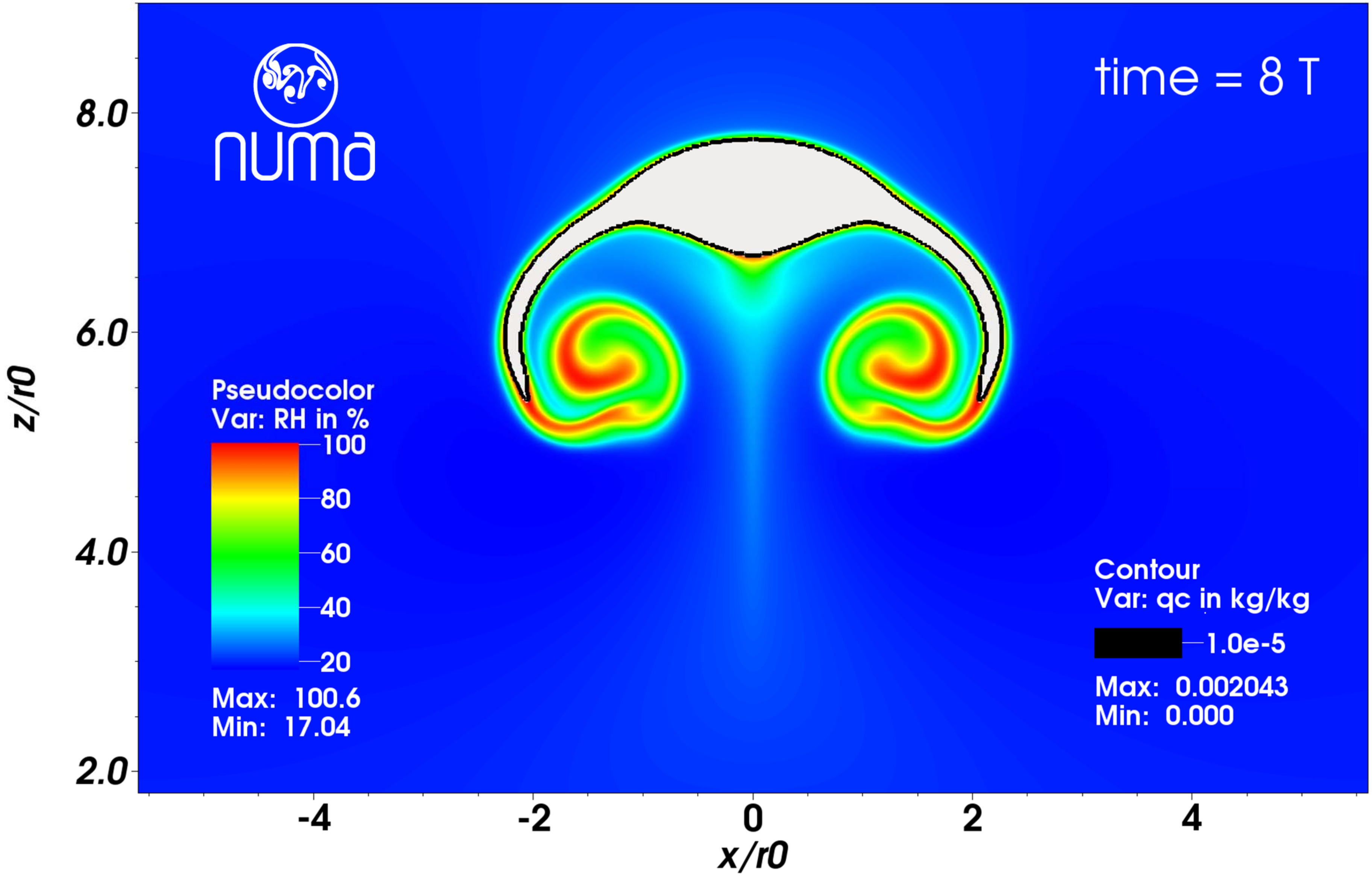

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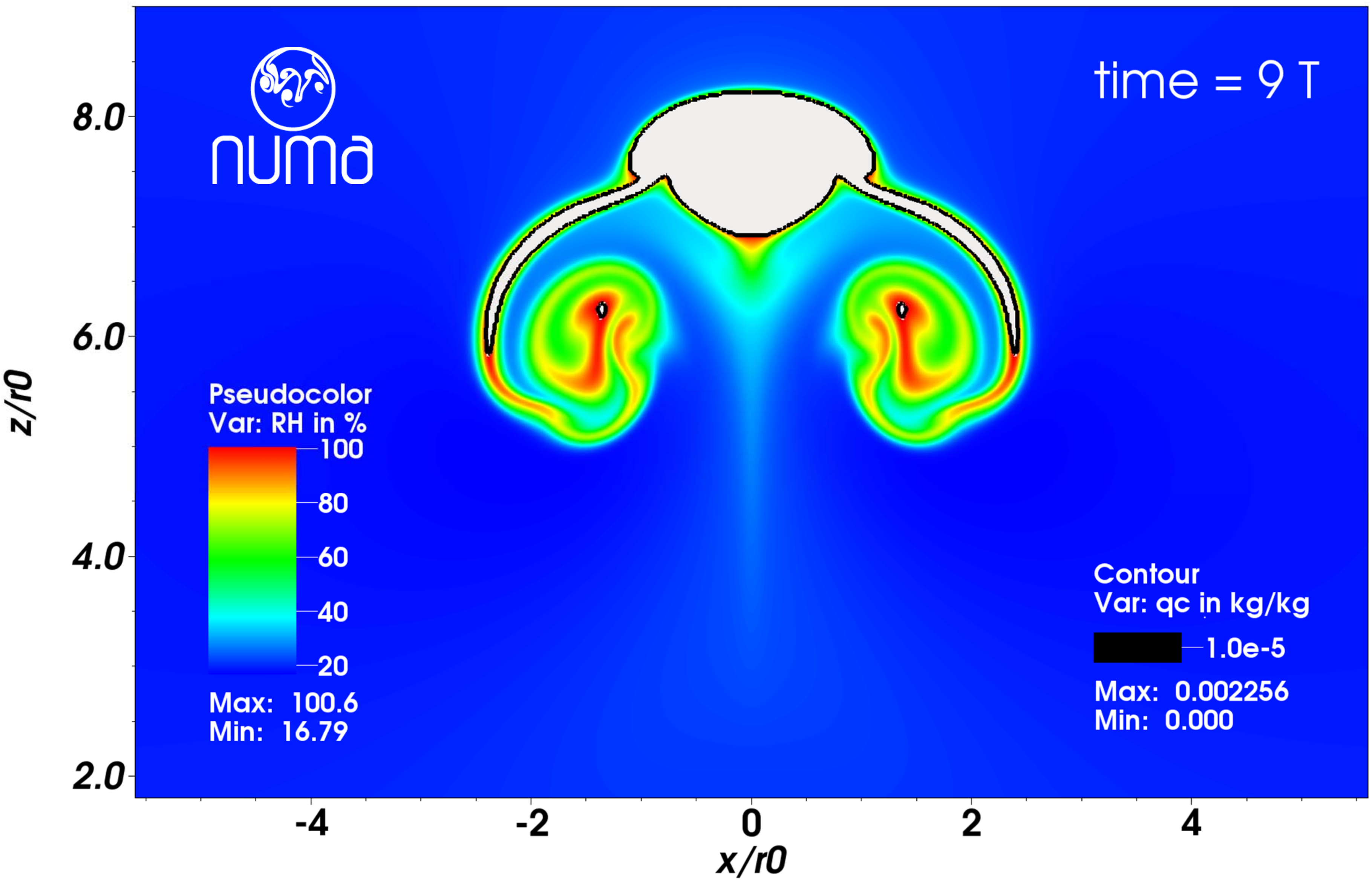

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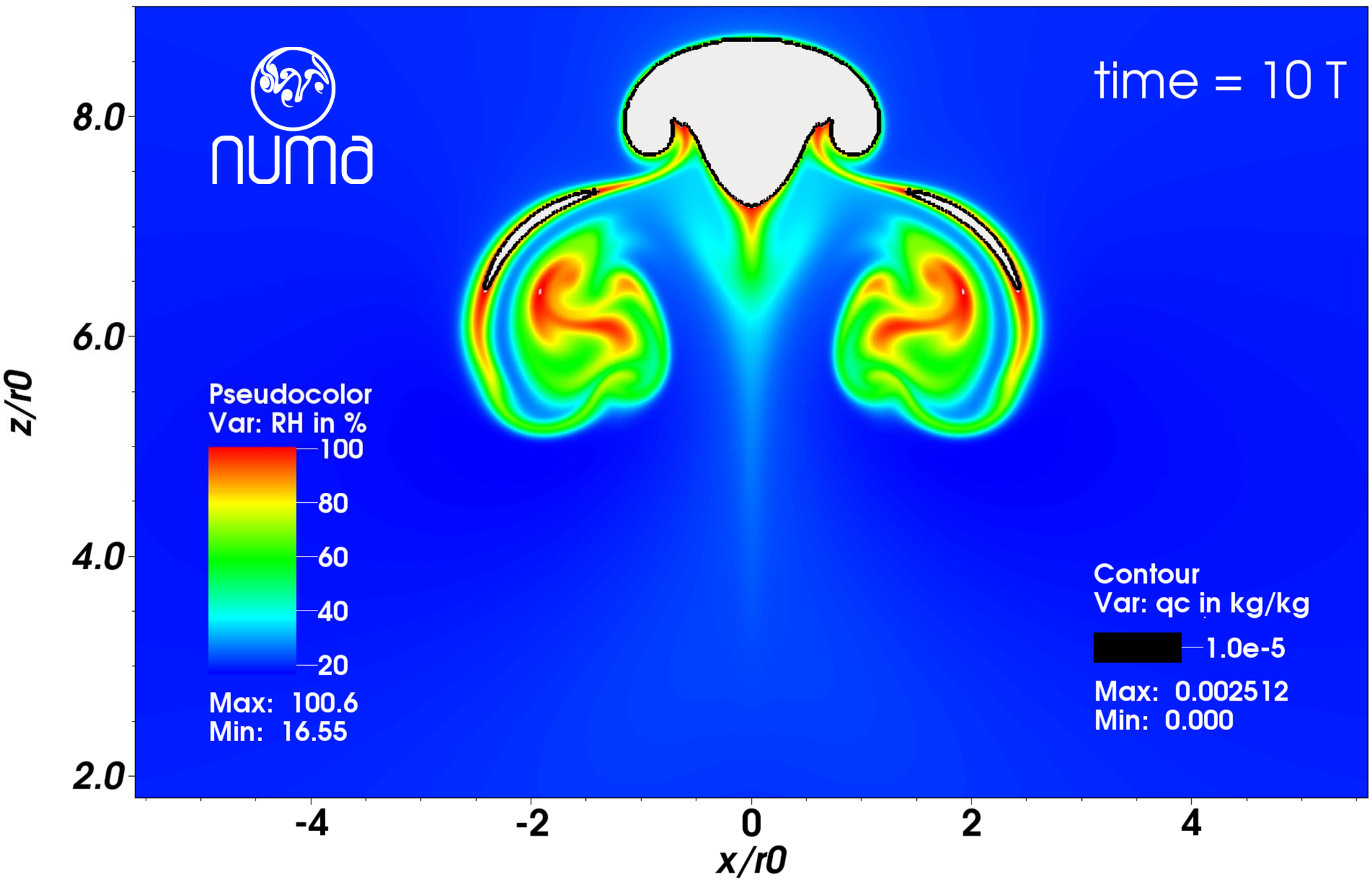
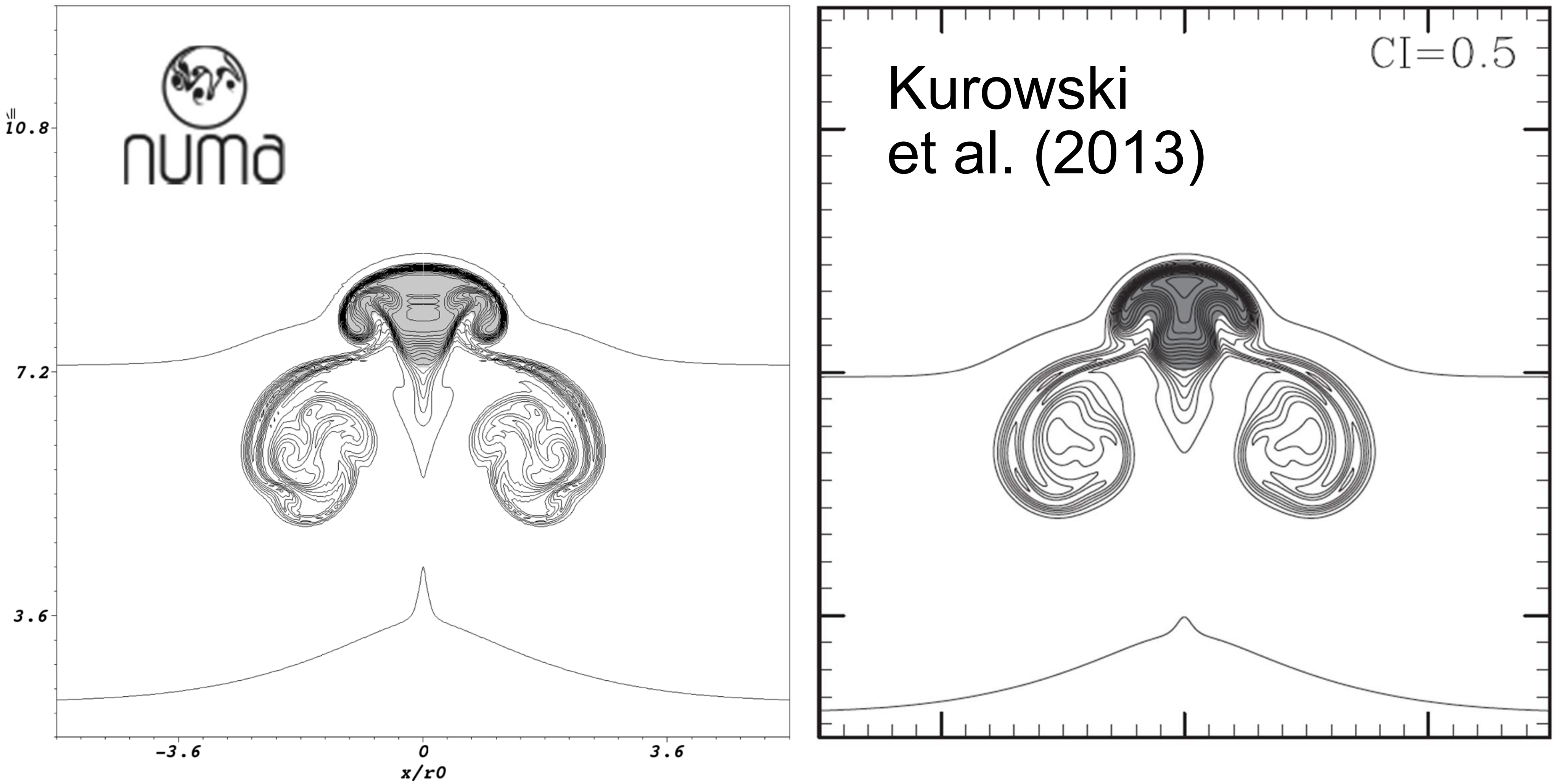


moist bubble

comparison with Kurowski et al. (2013)



contour lines: total water mixing ratio q_t, contour interval: 0.5gr/kg

convergence for moist bubble

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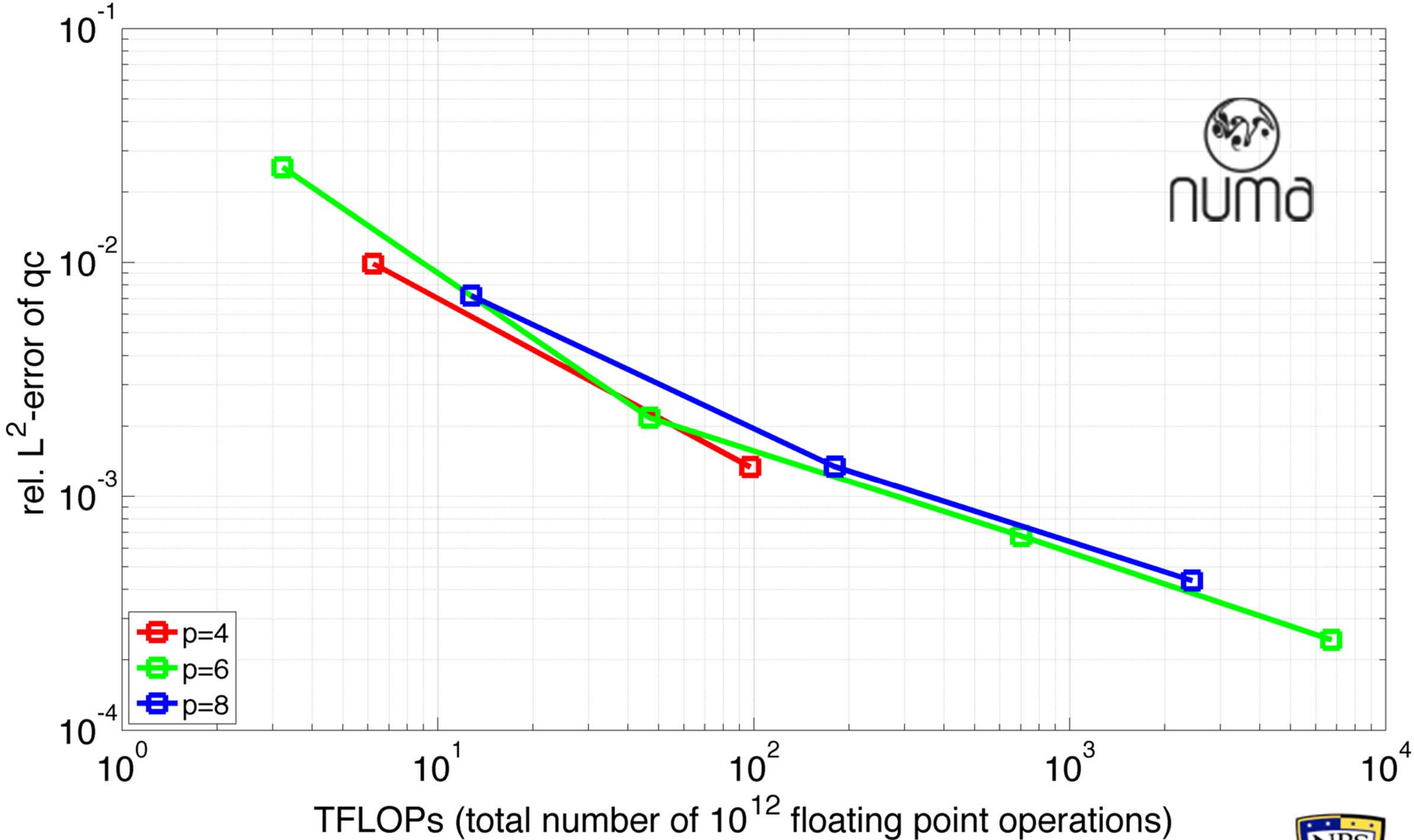

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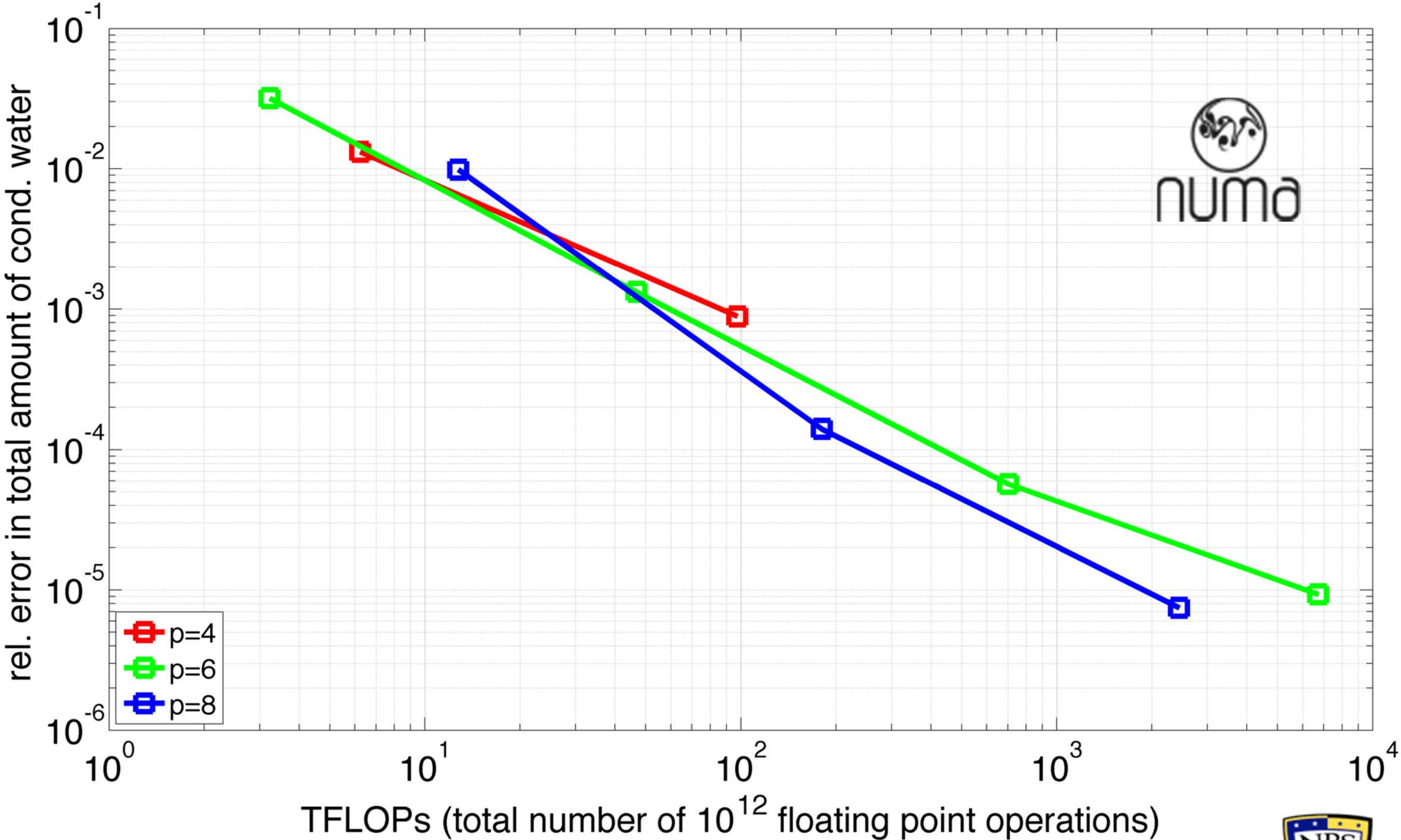

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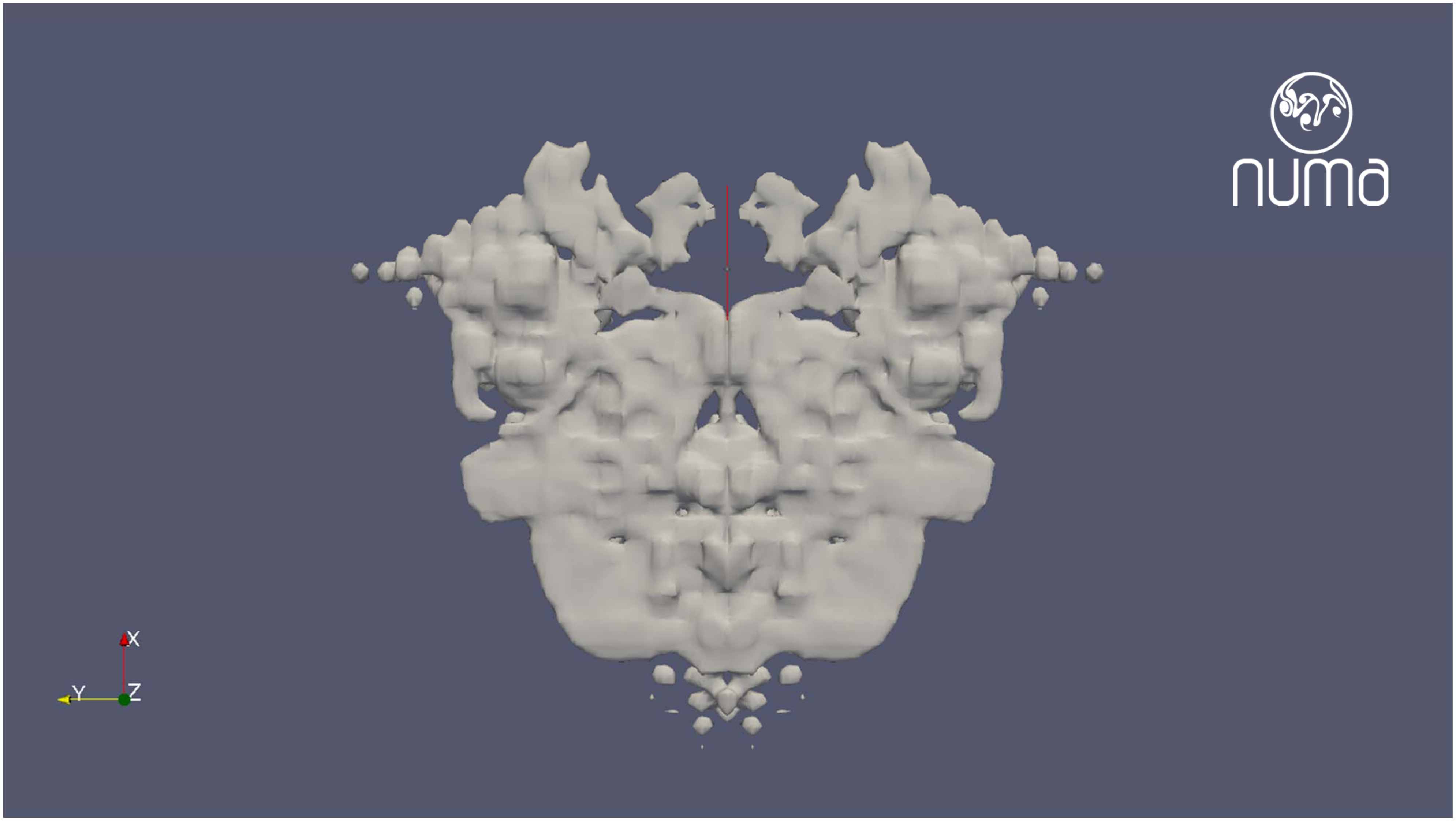
Open question: can we develop numerical methods and physical parameterizations that are specifically designed for each other?

Super cell simulation at fourth order

isosurface of cloud water content q_c=0.0035 at t=7500s



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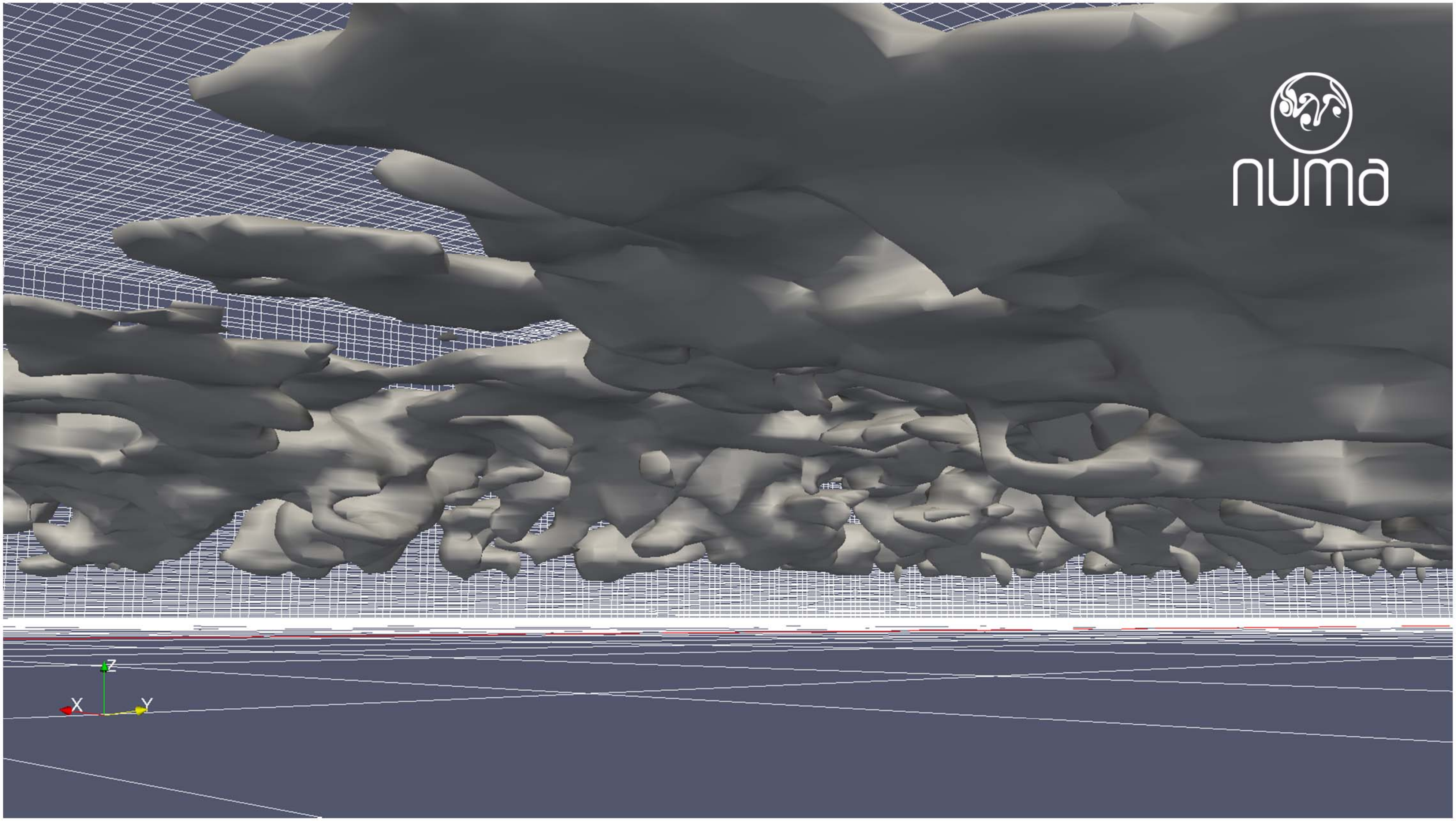

Super cell simulation at fourth order

visualization with Maya® (see http://anmr.de for instructions)

Thank you for your attention!